Application of Radiation Sources in Steel Industry in India

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ABSTRACT

The applications of ionizing radiation sources (radioisotope and X-ray) in India have registered the phenomenal growth for beneficial uses in medicine, industry, agriculture, research and training. In industry, there are different applications of radioisotopes viz. tracer studies, nucleonic control systems (NCS), i.e. nucleonic gauges; radiography for non-destructive testing (NDT) and radiation processing of food and health care products. With the obvious beneficial use of radiation sources, there is also concern about the likelihood of harmful effects of radiation, which necessitates the effective regulatory control over radiation sources. The comprehensive regulatory programme has been established in the country and the requirement of licence for handling of radiation sources in India is a statutory requirement as per Atomic Energy (Radiation Protection) Rule, 2004. The NCS find many non-destructive applications in steel industry, such as in situ determination of thickness of steel plate(s); measurement of density and determination of elemental composition of materials; level measurements; control of process material in closed containers i.e. mould level measurement; moisture content in blast furnace; analysis of ores and minerals. The type of radiation used includes gamma, X-rays, XRF and neutron sources with activity varying from several MBq to few GBq. There are about 1500 number of NCS installed and operated in around 150 numbers of steel and allied industries all over the country. The NDT by radiation sources play important role in verifying integrity of steel structure. The radiation equipment (i.e. NCS and radiography device) with several built-in-safety features and trained/ certified operating staff ensures safe handling and use of radiation sources in industry. While handling of radiation sources, unusual occurrences do occur.

This paper describes the major applications of radiation sources and regulatory aspects for ensuring safe handling of radiation sources in steel industries in India.

Introduction

The nuclear control system and the industrial radiography are non-destructive techniques which has variety of applications in steel industries. The NCS find many non-destructive applications in steel industry, such as in situ determination of thickness of steel plate, measurement of density, determination of composition of materials, level measurement, control of process material in closed containers i.e. mould level measurement, moisture content in blast furnace, analysis of ores & minerals etc. The NCS have been widely used by various industries to improve the quality of product, optimize processes, save energy & materials. NCS is basically control of instrument & analysis as based on the interaction between ionizing radiation & matter. One of the most significant changes in recent years has followed the introduction of on-line processing and display. Detector technology is rapidly changing and a number of solid state and other detectors are presently being developed that can be operated without cooling. NDT by radiation sources also play important role in verifying integrity of steel structure such as welds, joints, casting in steel & light alloy such as car wheels.

Worldwide Status of Nuclear Control Systems (NCS)

The application of NCS, i.e. nucleonic gauges began in sixties in the developing countries and there are around 20, 000 NCS being used during 1962-63 as per the International Atomic Energy Agency(1) (IAEA) survey and most of them are used for level, thickness and density measurement. Statistics of 1975 showed the number of NCS may be more than 1,00, 000 units. The United States of America and Russian Federation are the major producer and user of the NCS system. The high number of NCS in developed countries was mainly reflection of industrial development in these countries in comparison to the others. Around 6500 NCS units might be a typical number for many developed countries in 1995-2000. Number of nuclear control systems worldwide could be estimated around 3,00,000 as on date. As per the national inventory of radiation source in our country, there are around 8500 number of NCS being used for various applications is shown by following chart.

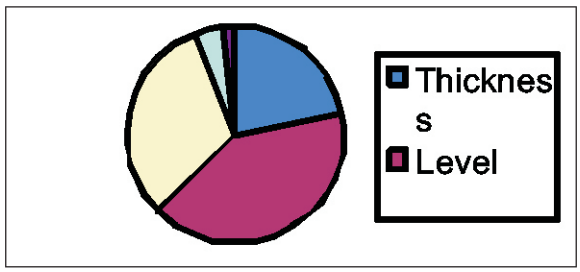

Fig.1: NCS being used in India

Advantage of NCS over Conventional Gauging Systems

The competition from alternative methods shows that NCS have survived and prospered in the past because of their superiority in certain areas to conventional methods. The success of NCS is due primarily to the ability, conferred by their unique properties, to collect data, which cannot be obtained by other investigative techniques or to provide simple, reliable, and cheap solutions that compete favorably with those involving non-radioactive equipment. NCS permits measurements in difficult conditions, e.g. in corrosive media, it is ideal for dangerous industrial environments, including high-temperature and high-pressure situations; also non-invasive - no physical contact is required between the sensor and the material and portable energy source and mature technology.

There are some disadvantages to the use of radioactive sources, like need for precautions to prevent exposure of individuals to harmful radiation, always emits radiation, thus requiring significant attention to storage, loss of the source can create an environmental and health hazard and disused sources require appropriate safe disposal as per the safety regulations.

Applications of Nuclear Control System in Steel

Thickness Measurement

The thickness gauging systems are used worldwide for variety of applications in steel industries which includes accurate and reliable measurement of thickness (steel sheets) in cold rolling mill and galvanization, Tin Coating, coating weight measurement (zinc, tin, and aluminum). It provides on-line, non-contact measurement through a combination of application matched sensors, frames, system functions and interfaces. It uses radioisotope or X-ray energy sources and ion chambers detectors to provide the most reliable and stable data. The principle of thickness gauge is based on the fact that radiation suffers a reduction in intensity or energy flux as a result of transmission through matter. The choice of radioisotope depends on the thickness of material for which the gauge is needed. Figure 2 illustrates the principle of thickness measurement. The attenuation follows the empirical equation

$$I = I_0 B_o * e^{-\mu_m . t}$$

Where

I_0 = Intensity of radiation with zero thickness

I = Intensity of radiation with absorber of thickness 't'

B = is buildup factor

μ_m = Mass attenuation coefficient (absorption coefficient) in cm^2/g,

μ_m = μ_{linear}/ρ, dependent on energy of radiation (ρ = Density of absorbing material in g/cm3)

In India there are around 15 number of NCS containing very high activity Cs137 sources of the order of 1.11 TBq to 5.55 TBq (150 Ci) for thickness measurement upto 150 mm of steel and around 780 number of NCS commonly used with low activity source for typical range of thickness as given in table 1.

Table 1. The radiation sources in use with typical range of thickness

Radiation sources	Steel thickness in mm (ρ =7.9 g/cm^3)
Am-241	10
X-ray	20
Cs-137	100
Co-60	150

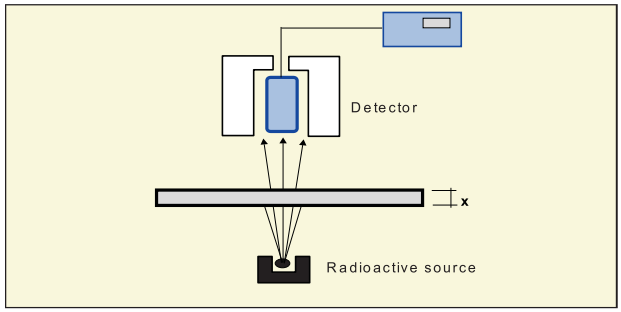

Fig . 2: NCS for thickness measurement

Density Measurement

The density measurements can be carried out directly in a product line or in a container. It utilizes the radiometric measurement method, i.e. the physical law of attenuation of gamma radiation passing through the product being measured. The resulting measurement effect is the ratio I/I0 between the intensity I0 with no material and the transmitted intensity I, which is attenuated by the product being measured. The transmitted radiation picked up by the detector represents the density of the product being measured. The Cs137 source is preferred for density measurement because of the absorption coefficients for Cs137 are virtually constant, i.e. independent on atomic number of the material unlike Am241 and Cm244, where the absorption coefficient rises significantly with the atomic number.

Its energy is sufficient to penetrate commonly used pipe and container walls, due to the lower energy, the measuring effect is better than with Co60. The radiation is attenuated according to the following formula:

$$I = I_0 * e^{-\mu' + \rho + d}$$

Where, ρ = Density of absorbing material in g/cm3
d = Thickness of absorbing material in cm

The equation shows that with a given source and the respective mass attenuation coefficient μ' the measuring effect is dependent only on the product density 'ρ' and the measuring path length

'd'. This measuring method is not affected by any chemical and virtually no physical properties of the product being measured, because of this reason, the radiometric measuring principle ensures high reliability and low maintenance. In India there are around 250 number of NCS containing Cs137 sources for density measurement.

Level Measurement

Nucleonic level gauge is a simple and reliable gamma ray level switch designed to monitor and provide precise on-off control of liquid, slurry or solid levels in a vessel without probe immersion. These gauges are used in coal handling thermal plants, cement plants, steel plants and ore handling plants. There are around 2859 level gauges used in India for level measurement application in various industries.

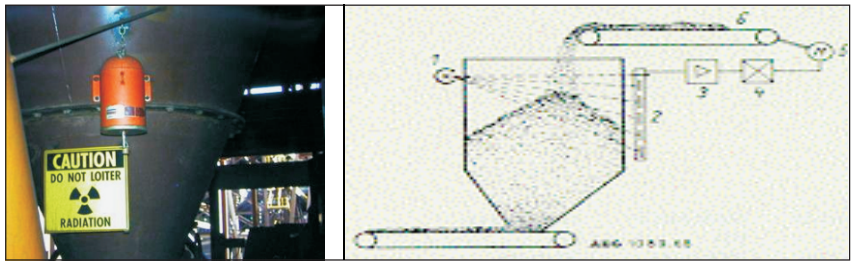

Fig. 3: NCS for level measurement

The most widely used level gauge in steel industry is mould level measurement with Cs137 and Co60 source depending on the cross-section of the container, vessel. Blast furnaces that are employed in steel making, often uses Co60 sources for mould level measurement. There are around 350 numbers of NCS involved in level measurement in steel industries.

Moisture Measurement

Nucleonic moisture gauge is a non-contact measurement system designed exclusively for measurement of the moisture content of raw materials like iron ore, sinter mix, coke, coke breeze, coal and lime stone etc. with use of Am241-Be neutron sources. The moisture gauge is preferably used in blast furnaces to measure moisture content. There are around 50 number of NCS used for moisture measurement in steel industries.

X- Ray Fluorescence (XRF)

Elements on removal of bound electrons emits X-rays, whose energy would be characteristics of the element, the detection of characteristics X-rays and the measurement of their intensity would help in the determination of the presence and concentration of the element of interest. This principle can be used for analysis of mineral ores and alloys, determination of coating thickness and composition of mixtures in steel industries. Depending on the range of measurement the radiation sources Cd, Fe, Am and Cm or combination of them are being used in XRF gauges for analysis of

stainless steel elements such as Ti, V, Cr, Mn, Fe, Co, Ni, Cu etc. There are around 132 XRF devices used in India.

Coating Gauges

The backscattering principle is used for coating thickness measurement. In steel industries it is used for determination of sheet metal thickness upto 12 mm of steel, thickness of coating applicable in galvanizing industries. The coating weight gauge is used to measure several metal coatings, typically zinc, aluminum (or a combination) and tin.

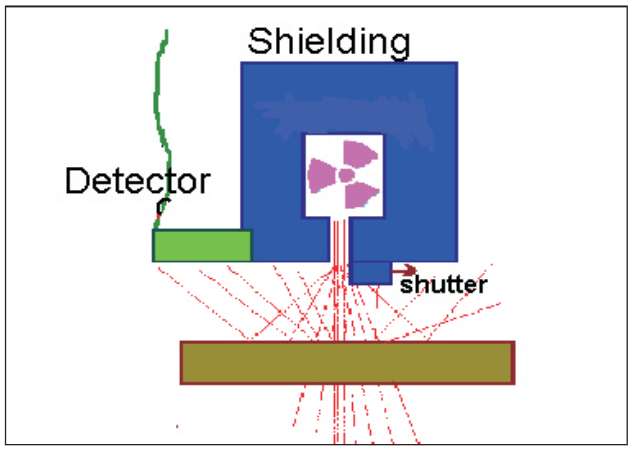

Fig. 4: Backscatter gauges for Coating thickness measurement

Industrial Radiography for NDT in Steel Industry

Non-destructive testing (NDT) comes in many forms, one of the most popular is radiography, which uses a radioisotope or X-ray source. NDT radiography is used extensively in the petroleum, chemical and nuclear industries, as well as on assembly lines to test consumer goods. NDT by radiation sources also play important role in verifying integrity of steel structure such as welds, joints, casting in steel & light alloy such as car wheels. Pipelines, too, are prime NDT candidates - both during installation and maintenance - to ensure that welds remain intact.

Non-destructive testing developed worldwide, and radiography is a classical component, in use with other, non-nuclear methods. In NDT radiography, gamma rays from a sealed source or X-rays are directed through the object, and the results shown on film or other media. Imperfections are indicated as the density changes - just as a body X-ray reveals broken bones. A recent development is real-time radiography, where faults can be evaluated on a computer screen for assembly-line inspections and troubleshooting. The gamma sources such as Ir192, Co60 with activity of the order of 1.3 TBq to 5.55 TBq are being used for this purpose. There are about 500 institutions possessing around 2000 radiography devices being used for NDT applications in India.

Unusual Occurrences

Because of maximum built-in-safety features and minimum human intervention during the operation of the NCS, there are rare chances of the personnel exposure due to the radiation sources in use. The greatest problem arises at the end of useful life of the sources itself or the plant or equipment where it is installed. There are several national and International unusual incidents which include lost/missing, theft, fire hazard, melting of source in furnace, unsafe disposal, and steel contamination. Many accidents/incidents occurred with disused or abandoned sources. In India there are around 16 unusual incidents reported to AERB till date out of which 8 occurred in steel industries including overexposure to workers in one of the incident.

The major causes of the loss of control over the radiation sources in NCS are (i) location of installation is unsuitable for continuous monitoring, (ii) accumulation of layers of dirt, oil which may cover warning labels, because of which the sources is simply left at the site, storage and loose it track to unsafe disposal. There is possibilities that most likely the sources ends up in the metals recycling industries, the sources could be melted down, resulting in the contamination of the foundry and radioactive material incorporated into manufactured articles. The use of radioactive materials in industry & the importation of scrap steel from other countries crate the potential threat for radioactive contamination in the material stream. This potential threatens human health and the environment as well as economy of the steel industry. There are number of incidents of rejection of steel consignment exported from India to other countries due to radioactive contamination.

Regulations for Use of Radioisotopes in India

In India the Atomic Energy Act 1962, is the prime legislation which controls the use of atomic energy for peaceful applications. The Atomic Energy Regulatory Board (AERB) is the national regulatory body and Chairman AERB is the competent authority for enforcing the regulations in respect of use of radiation sources in India. Particular emphasis is placed on designing built-in-safety so as to minimize human intervention, control of leakage radiation on and around the radiation device, the reliability of the radiation device & its components to withstand worse environmental conditions and endurance with long term use. AERB issues type approval to radiation equipment based on the National/International safety standards viz. ISO 7205, DIN, ISO3999 or AERB/SS-1(2) and AERB/SS-2(3) to ascertain adequate built-in-safety as far as operational safety is concerned in respect of NCS and radiography devices. The requirement of license/authorization for handling of radiation sources in India is a statutory requirement as per Atomic Energy (Radiation Protection) Rules, 2004(4). For issuing such licence/authorization, AERB requires availability of adequate number of trained personnel, such as Radiological Safety Officers (RSOs) and operators, details about the radiation device, the purpose for which it will be used, radionuclide(s), & activity, undertaking from the supplier for taking back the disused sources for safe disposal, information regarding the personnel who will be using the equipment

The control over radiation devices is ensured by periodic submission of safety status report and random inspection of some of the user institution possessing NCS or radiography devices.

Enforcement action may be taken against the user if the level of radiation protection & safety are considered unacceptable.

Conclusion

Overall radiation protection of personnel and safety in use of radiation sources is a function of inherent built-in safety features and safe operating and maintenance procedures. Emergency planning and preparedness helps in mitigating the consequences in case of unusual occurrences. The regulatory control briefly outlined above has evolved over the years from experience gained in this field. The high standard of safety can be achieved through the inherent safety features incorporated in the design of radiation installation and sources and administrative control. The complete involvement of the persons involved in handling of the radiation sources and their commitment to safety and security culture is essential to handle the radiation sources safely and efficiently. The prime responsibility for ensuring safety and security of radiation sources rests with the employer/operating organization and the radiation workers.

Acknowledgement

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